Low-energy M1 strength in the ^{7}Li$(p,\gamma_0)^8$Be reaction

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(February 9, 2008)

Abstract

The ^{7}Li$(p,\gamma_0)^8$Be reaction is studied in a microscopic cluster model. All relevant subsystem properties are well reproduced. The calculated astrophysical S factor is in good agreement with the experimental data, although some $M1$ strength is missing in the $1^+;1$ resonance region. There is no contribution from the $1^+;0$ state. We estimate an $M1$ strength of 3.5% at 80 keV. By assuming the experimental resonance parameters and channel spin ratio for the first 1^+ state that $M1$ strength is 6.3%, in good agreement with an R matrix analysis. The large (20%) $M1$ strength determined from a transition matrix element analysis may be caused by assuming a vanishing $0p_{3/2}$ spectroscopic factor, which is not supported by shell model calculations.

Keywords: NUCLEAR REACTIONS ^{7}Li$(p,\gamma_0)^8$Be, solar neutrinos, cluster model, shell model
PACS: 25.40.Lw; 26.65.+t; 21.60.Gx; 21.45.+v; 21.60.Cs; 27.20.+n

I. INTRODUCTION

Astrophysical processes most often involve charged particle nuclear reactions at very low energies. The cross sections of such reactions decrease exponentially with decreasing energy, making their laboratory measurements extremely difficult. One of the most important reactions in nuclear astrophysics is the radiative proton capture on ^{7}Be. This reaction produces ^{8}B in the Sun, whose β^+ decay is the main source of high-energy solar neutrinos. That ^{7}Be is radioactive makes the measurement of the low-energy $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ cross section even more difficult. There is a considerable spread among both the experimental (see, e.g., [1]) and theoretical (see, e.g., [2]) values of the low-energy astrophysical S_{17} factor. However, a common feature in all of these analyses is the assumption that the cross section at low energies ($E < 200$ keV) is dominated by the $E1$ transition. Hence the extrapolated astrophysical S factor is flat.

The $^7\mathrm{Li}(\vec{p},\gamma)^8\mathrm{Be}$ reaction was studied for energies from 0 to 80 keV by Chasteler *et al.* [3] with the hope that the somewhat easier experimental situation (^{7}Li is stable) might allow one to gain some insight into the similar $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ process. A considerable forward-backward asymmetry was found in the angular distribution of the emitted photons, indicating a non-negligible $M1$ (p-wave) strength at such low energies. A transition-matrix element (TME) analysis of the data was performed, resulting in two possible values of the $M1$ strength of 20% and 80%. It was suggested that the situation may be similar in the case of the $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ reaction. If that were so, then the lowest energy (≈ 100 keV) experimental cross section values would contain a 20% (80%) $M1$ contribution. Thus, as the $M1$ cross section becomes negligible at lower energies because of the centrifugal barrier, the S factor would not be flat but decreasing with decreasing energy, and the zero energy S_{17} factor would be 20% (80%) smaller than currently believed.

Rolfs and Kavanagh [4] suggested that the observed low-energy $M1$ strength of the $^7\mathrm{Li}(p,\gamma)^8\mathrm{Be}$ reaction comes from the tail of the 1^+ state at $E_{lab} = 441$ keV. More recently, the astrophysical S factor of the $^7\mathrm{Li}(p,\gamma)^8\mathrm{Be}$ reaction was accurately measured between 100 and 1500 keV by Zahnow *et al.* [5]. The data were interpreted again by assuming that the small $M1$ contribution comes from the tail of the 1^+ resonance. Weller and Chasteler [6] pointed out that some of the formulae used in the previous analyses [4,5] were incorrect, and that the resonance tail could only result in a 2% p-wave contribution, much smaller compared to the earlier estimates. Barker [7] achieved acceptable fits to the measured angular distributions and analyzing powers by attributing the p-wave $M1$ contribution to the tails of the low-energy resonances. He obtained an $M1$ strength of $5-6\%$, again much less than that reported by Chasteler *et al.* However, to achieve these fits, some of the spectroscopic amplitudes needed the opposite signs to those obtained from the shell model.

Barker also noted [7] that the analogue of the $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ reaction in ^{8}Be would be the one which leads to the $2^+;1$ isobaric analogue state of the ground state of ^{8}B. Such a measurement was performed by Godwin *et al.* [8] and no indication of any low-energy $M1$ strength was found. Therefore, it may be assumed that the standard extrapolation of the $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ S factor is correct and reliable. However, the origin of the discrepancies among the various analyses of the $^7\mathrm{Li}(p,\gamma)^8\mathrm{Be}$ reaction is still not understood.

Herein, we study the role of the $M1$ transition in the $^7\mathrm{Li}(p,\gamma)^8\mathrm{Be}$ reaction by using a microscopic eight-body model.

II. MODEL

Our model is a microscopic multi-cluster (^{4}He+^{3}H+p; ^{4}He+^{3}He+n; α+α) Resonating Group Method (RGM) approach to the eight-nucleon system. The trial function of the eight-body system is

$$\begin{aligned}\Psi = &\sum_{S,l_1,l_2,L} \mathcal{A}\left\{\left[\left[\Phi^p(\Phi^\alpha\Phi^t)\right]_S \chi_{[l_1l_2]L}(\boldsymbol{\rho}_1,\boldsymbol{\rho}_2)\right]_{JM}\right\} \\ &+ \sum_{S,l_1,l_2,L} \mathcal{A}\left\{\left[\left[\Phi^n(\Phi^\alpha\Phi^h)\right]_S \chi_{[l_1l_2]L}(\boldsymbol{\rho}_1,\boldsymbol{\rho}_2)\right]_{JM}\right\} \\ &+ \mathcal{A}\left\{\left[\Phi^\alpha\Phi^\alpha\chi_L(\boldsymbol{\rho})\right]_{JM}\right\}, \end{aligned} \tag{1}$$

where $\mathcal{A}$ is the intercluster antisymmetrizer, the Φ cluster internal states are translationally invariant harmonic oscillator shell model states (α = ^{4}He, t = ^{3}H, and h = ^{3}He), the $\boldsymbol{\rho}$ vectors are the different intercluster Jacobi coordinates, l_1 and l_2 are the angular momenta of the two relative motions, L and S are the total orbital angular momentum and spin, respectively, and [...] denotes angular momentum coupling. The sum over S, l_1, l_2, and L includes all physically relevant angular momentum configurations. In order to project out pure ^{7}Li and ^{7}Be states, the angular momenta are recoupled in the 7+1 channels following the scheme

$$[(l_1,l_2)L,(s_1,s_2)S]J \rightarrow \Big[[(l_1,s_1)I_7,s_2]I,l_2\Big]J, \tag{2}$$

where I_7 is the total spin of the seven nucleon system, and I is the channel spin.

The ^{7}Li$(p,\gamma_0)^8$Be radiative capture cross section is calculated perturbatively [9], and is given by

$$\begin{aligned}\sigma = &\sum_{\Omega,\lambda} \frac{1}{(2I_7+1)(2s_2+1)} \frac{8\pi(\lambda+1)}{\hbar\lambda(2\lambda+1)!!}\left(\frac{E_\gamma}{\hbar c}\right)^{2\lambda+1} \\ &\times \sum_{l_\omega,I_\omega} (2l_\omega+1)^{-1} |\langle \Psi^{J_f}||\mathcal{M}^\Omega_\lambda||\Psi^{J_i}_{l_\omega,I_\omega}\rangle|^2, \end{aligned} \tag{3}$$

where I_7 and s_2 are the spins of the colliding clusters, λ denotes the rank of the electromagnetic operator $\mathcal{M}^\Omega_\lambda$ ($\Omega = E$ or M), ω represents the entrance channel, and J_f and J_i is the total spin of the final and initial state, respectively. The initial wave function $\Psi^{J_i}_{l_\omega,I_\omega}$ is a partial wave of a unit-flux scattering wave function. We follow the convention of Edmonds [10] for the reduced matrix elements.

The final ^{8}Be ground state is unbound in the $\alpha+\alpha$ channel which, in principle, could cause convergence problems. However, this is not the case here since the ^{7}Li+p and ^{7}Be+n channel wave functions are orthogonal to the $\alpha+\alpha$ one in the asymptotic spatial region. This feature allows us to treat the ^{8}Be ground state as a pseudo-bound state in the $\alpha+\alpha$ configuration. The orthogonality also indicates that the ^{7}Li+$p \rightarrow \alpha+\alpha$ contribution to the cross section is small, and that the inclusion of the $7+1$ configurations in the ^{8}Be ground state is important.

Putting (1) into the eight-nucleon Schrödinger equation which contains the nucleon-nucleon (NN) strong and Coulomb interactions, we arrive at an equation for the intercluster

relative motion functions χ. For the 0^+ bound state these functions are expanded in terms of products of tempered Gaussian functions $\exp(-\gamma_i \rho^2)$ [11] with different ranges γ_i for each type of relative coordinate. The expansion coefficients are determined from a variational principle. The scattering states are calculated from a Kohn-Hulthén variational method [11] for the S-matrix, which uses square integrable basis functions matched with the correct scattering asymptotics. Then, using the resulting eight-nucleon wave functions, the cross section (3) is evaluated.

III. RESULTS

The model used herein is essentially the same as that used in Refs. [12,13], which was used to describe the ^{7}Li, ^{7}Be, ^{8}Li, and ^{8}B nuclei, and the $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ reaction. In those calculations all possible arrangements of the three clusters were included, e.g., $(\alpha h)p$, $(\alpha p)h$, and $(hp)\alpha$ for ^{8}B. However, we consider only the ^{7}Li+p and ^{7}Be+n configurations due to computational constraints. The results of a full model and a model which contains only $7+1$ configurations are quite similar [13], provided the experimental subsystem properties (separation energies, channel thresholds, sizes, etc.) are correctly reproduced in each.

We use the same parameters for the description of ^{7}Li and ^{7}Be, and the same NN interaction (Minnesota force) as in Ref. [12]. Using these parameters, the ^{7}Li and ^{7}Be properties are well reproduced [12]. The calculated relative binding energies ^{7}Li(g.s.)–^{7}Be(g.s.) and ^{7}Li(g.s.)–^{8}Be(g.s.) are also close to the experimental values. Note that in eq. (3) the experimental value for E_γ is used.

We calculate the $E1$, $E2$, and $M1$ cross sections for the capture to the ground state of ^{8}Be. An unambiguous treatment of the transition to the broad 2^+ excited state of ^{8}Be would require a more sophisticated model.

As the final state is $J^\pi = 0^+$, the $E1$, $E2$, and $M1$ transitions occur from 1^-, 2^+, and 1^+ initial scattering states, respectively. The 1^- and 2^+ partial waves are non-resonant above the ^{7}Li+p threshold, while there are two 1^+ resonances at $E_{c.m.} = 386$ keV ($\Gamma = 11$ keV, $T = 1$) and $E_{c.m.} = 897$ keV ($\Gamma = 138$ keV, $T = 0$). In order to explore the role of the $M1$ capture at low energies, the properties of the 386 keV state must be reproduced. We decreased the exchange mixture parameter of the NN interaction by 0.4% and achieved 386 keV position and 13 keV width. The energy and width of the second 1^+ ($T = 0$) state are 1050 keV and 342 keV, respectively, in our model. These resonance parameters were determined from an analytic continuation of the scattering matrix to complex energies [14]. As the $T = 0$ state is higher in energy than experimentally observed, and much broader, it does not have any observable effect on the low-energy cross section. This is not a serious problem, as only the first state is expected to contribute significantly to the cross section at ≈ 80 keV [4,6]. Note that the 0.4% change in the NN interaction has a negligible effect on the subsystem properties.

We generate the 0^+ bound state and 1^-, 2^+, and 1^+ scattering states using the same force in all cases. In order to account for specific distortions of ^{7}Li and ^{7}Be, we describe these nuclei by using six basis states. The resulting large number (50–60) of coupled channels required special numerical attention to keep high precision in the scattering calculations.

The result of the calculation of the ^{7}Li$(p,\gamma)^8$Be cross section is presented in Fig. 1 in terms of the astrophysical S factor

$$S(E) = \sigma(E) E \exp\Big[2\pi\eta(E)\Big], \tag{4}$$

where η is the Sommerfeld parameter. As our $E2$ cross section is 2–3 orders of magnitude smaller than the $E1$, it is not displayed. There is no contribution to the cross section coming from the second 1^+ state, as expected. The nonresonant part of the cross section and the first 1^+ state is well reproduced, although some $M1$ strength is missing in the resonance region.

Note that, as discussed above, inclusion of the ^{7}Li+p and ^{7}Be+n configurations in the ground state of ^{8}Be is necessary. The contribution to the cross section from the $\alpha+\alpha$ final state configuration is very small. This 0^+ state is thought to be one of the pure two-cluster $(\alpha+\alpha)$ systems [15]. However, by adding the high-lying $7+1$ channels to the $\alpha+\alpha$ configuration, one gains 1–2 MeV of energy in the 0^+ state, indicating that this state may not be a pure $\alpha+\alpha$ configuration.

In our model the 386 keV $(T=1)$ resonance is dominated by the $I=1$ channel spin. This is in contradiction to experiment [16], which gives 3–5 for the ratio of the $I=2$ to $I=1$ channel spin contributions to the cross section. The same $I=1$ dominance was also observed in the calculations of the 1^+ isobaric analogue state in ^{8}Li and ^{8}B. In order to understand the origin of this $I=1$ dominance, we calculated the percentages of the orthogonal (LS) components in ^{8}Li (which is the only two-body bound state in the triplet). The $(LS)=(1,0)$, $(0,1)$, $(1,1)$, and $(2,1)$ components have 83.4%, 0.03%, 13.3%, and 3.2% weights, respectively. However, the contribution of the largest component, $(1,0)$, to the $I=2$ channel spin state is zero, and hence the $I=1$ configuration dominates. Very similar (L,S) components were found in a different three-body model [17] using completely different cluster-cluster interactions. That model would also predict a dominant $I=1$ component in the $A=8$ $1^+;1$ triplet. In the second 1^+ $(T=0)$ state, our model predicts a dominant $I=2$ component. It remains a question as to whether the mixing of these states could influence the experimental determination of the channel spin ratio.

As a comparison to the results obtained from our RGM model, the $I=1,2$ spectroscopic amplitudes were calculated using wave functions obtained from a large space shell model calculation. The interaction used was that of Zheng *et al.* [18], based on a multi-valued G-matrix calculation and defined within the complete $(0+2+4)\hbar\omega$ shell model space. The calculations were performed using the shell model code OXBASH [19]. The spectroscopic amplitudes $S_{I=1,2}$ are defined in terms of the shell model spectroscopic amplitudes by

$$S_I = \sum_j \alpha_{I,j}\theta_j, \tag{5}$$

where θ_j are the shell model spectroscopic amplitudes ($j=3/2$ or $1/2$),

$$\theta_j = \frac{1}{\sqrt{2J_f+1}} \left\langle J_f(^8\mathrm{Be}) \left\| a_j^\dagger \right\| I_7(^7\mathrm{Li}) \right\rangle, \tag{6}$$

and $\alpha_{I,j}$ are transformation coefficients for the recoupling of the angular momenta in terms of the channel spin, I,

$$[I_7, j]\, J_f \rightarrow \left[\left(I_7, \frac{1}{2}\right) I, l_2\right] J_f. \tag{7}$$

Table I lists the spectroscopic amplitudes, S_I, as obtained from our shell model calculation, along with those obtained from the calculation using the Cohen and Kurath (CK) $(6-16)$2BME $0p$-shell interaction [20]. Note that the contribution from higher shells to the amplitudes calculated in the $(0+2+4)\hbar\omega$ space is negligible. The CK amplitudes favor the $I=2$ channel spin for the $1^+;1$ state, while the Zheng ones support the results of our analysis. This discrepancy is the result of a slight redistribution of particle strength between the $0p_{3/2}$ and $0p_{1/2}$ orbits, as is illustrated in Table II. The spectroscopic amplitude, θ_j, for the capture to the $0p_{3/2}$ orbit is larger in the Zheng model, while there is a corresponding decrease in the magnitude for the capture to the $0p_{1/2}$ orbit. It is also interesting to note the signs of the channel-spin amplitudes for the $1^+;0$ state. In Barker's two-level R-matrix calculation [7], the signs of the reduced widths used were obtained from the shell model. However, Barker changed the sign of the $I=1$ amplitude relative to that of the $I=2$ one, in order to fit the data. Our shell model results does not support this sign change.

We note, that if our channel spin ratio is in fact wrong, then probably the singlet-odd component of the NN force is responsible for this failure. In our model we calculate the peak to 80 keV S factor ratio for the $I=1$ and $I=2$ channel spin contributions. Using these numbers we can estimate the $M1$ strength at 80 keV for any given channel spin ratio.

The necessity of the microscopic description of the ^{7}Li$(p,\gamma)^8$Be (in contrast to that for ^{7}Be$(p,\gamma)^8$B [21], for example) is demonstrated by noting that in a potential model the $I=2$ contribution would come almost exclusively from the internal magnetic moments of ^{7}Li and ^{7}Be. The orbital part of the $M1$ operator describing the relative motion (which strongly dominates the spin part) is a rank-zero tensor in spin space. Thus, for any non-vanishing cross section from the ^{7}Li–p relative motion, the initial and final channel spins must be equal. Hence, as the channel spin in the 0^+ is $I=1$, the $I=2$ orbital cross section is zero. In our microscopic model, the $I=2$ cross section comes mainly from nucleon exchange effects.

The S factor is displayed on a linear scale in Fig. 2. The nonresonant $E1$ component is in good agreement with the data. We emphasize that in our model all parameters are fixed. The requirement that all relevant properties of the subsystems be reproduced does not leave any room for adjustment of parameters.

The contribution of the $M1$ component to the total S factor at 80 keV is 3.5%. If one adopts a value of 3.2 for the $I=2/I=1$ channel spin ratio, together with the experimental width and peak value of the 386 keV resonance, this $M1$ contribution is 6.3%, consistent with the estimates by Barker [7]. The value of 20% determined from the TME analysis [3] may be due to the assumption of a negligible $0p_{3/2}$ spectroscopic factor. That assumption is not supported by the results of the shell model calculations presented in Table II.

IV. CONCLUSIONS

In summary, we have studied the low-energy ^{7}Li$(p,\gamma_0)^8$Be reaction in a microscopic cluster model. All relevant subsystem properties are well reproduced by our model. The parameters of the $1^+;T=1$ resonance in ^{8}Be are in good agreement with the experimental

values, while the $1^+;T=0$ state is much higher and much broader in energy compared to experiment.

We have calculated the $E1$, $E2$, and $M1$ cross sections perturbatively. The nonresonant $E1$ component agrees well with the experimental data, while the $E2$ contribution is negligible. The calculated full astrophysical S factor is in good agreement with the data of Zahnow *et al.* [5], except that the $1^+;0$ state does not contribute in our model, and some $M1$ strength is missing in the $1^+;1$ resonant region. This is partly caused by the fact that the width of the $1^+;1$ state is slightly larger compared to experiment.

Our model predicts that in the $A=8$, $1^+;1$ triplet the dominant configuration has $I=1$ channel spin. Consequently, the $^7\mathrm{Li}(p,\gamma_0)^8\mathrm{Be}$ $M1$ cross section is also dominated by the $I=1$ component at $E_{c.m.}=386$ keV, in contrast with the $I=2$ dominance observed experimentally. Results of large-space shell model calculations, which give a larger spectroscopic factor for the $I=1$ component in the $1^+;T=1$ state, seem to support our RGM result, although this depends sensitively on the distribution of strength between the $0p_{3/2}$ and $0p_{1/2}$ orbits. We note, however, that the total $M1$ cross section can be estimated for any channel spin ratio in our model, using the calculated $I=1$ and $I=2$ $M1$ components.

The calculated $M1$ strength at 80 keV is 3.5% in our model. If we assume the experimental peak height and width of the 386 keV resonance in the S factor, and the 3.2 I=2/I=1 channel spin ratio, the model predicts 6.3%, in good agreement the result of an R matrix analysis [7].

Our shell model calculations show that the $0p_{3/2}$ $^7\mathrm{Li}+p$ spectroscopic factor is larger than the $0p_{1/2}$ one in the $1^+;1$ state. Thus the assumption of a vanishing $0p_{3/2}$ spectroscopic factor in the TME analysis is incorrect. This may have led to the large $M1$ strength found therein.

ACKNOWLEDGMENTS

The work of A. C. was supported by Wolfgang Bauer's Presidential Faculty Fellowship (PHY92-53505). This work was also supported by NSF Grant No. PHY94-03666 (MSU) and by the US Department of Energy (Los Alamos). We thank Sam Austin, Fred Barker, Alex Brown, and Gregers Hansen for useful discussions.

REFERENCES

[1] R. W. Kavanagh, T. A. Tombrello, J. M. Mosher, and D. R. Goosman, Bull. Am. Phys. Soc. 14 (1969) 1209; R. W. Kavanagh, in *Cosmology, Fusion, and Other Matters*, edited by F. Reines (Colorado Associated University Press, Boulder, 1972); B. W. Filippone, A. J. Elwyn, C. N. Davids, and D. D. Koetke, Phys. Rev. Lett. 50 (1983) 412; Phys. Rev. C 28 (1983) 2222; P. D. Parker, Phys. Rev. 150 (1966) 851; Astrophys. J. 153 (1968) L85; F. J. Vaughn, R. A. Chalmers, D. Kohler, and L. F. Chase, Phys. Rev. C 2 (1970) 1657; T. Motobayashi *et. al.*, Phys. Rev. Lett. 73 (1994) 2680.

[2] C. W. Johnson, E. Kolbe, S. E. Koonin, and K. Langanke, Astrophys. J. 392 (1992) 320; P. Descouvemont and D. Baye, Nucl. Phys. A 567 (1994) 341; K. H. Kim, M. H. Park, and B. T. Kim, Phys. Rev. C 35 (1987) 363; H. Krauss, K. Grün, T. Rauscher, and H. Oberhummer, Ann. Phys. 2 (1993) 258; F. C. Barker and R. H. Spear, Astrophys. J. 307 (1986) 847; F. C. Barker, Phys. Rev. C 28 (1983) 1407; Nucl. Phys. A 588 (1995) 693; H. M. Xu, C. A. Gagliardi, R. E. Tribble, A. M. Mukhamedzhanov, and N. K. Timofeyuk, Phys. Rev. Lett. 73 (1994) 2027.

[3] R. M. Chasteler, H. R. Weller, D. R. Tilley, and R. M. Prior, Phys. Rev. Lett. 72 (1994) 3949.

[4] C. Rolfs and R. W. Kavanagh, Z. Phys. A 350 (1994) 93.

[5] D. Zahnow, C. Angulo, C. Rolfs, S. Schmidt, W. H. Schulte, and E. Somorjai, Z. Phys. A 351 (1995) 229.

[6] H. R. Weller and R. M. Chasteler, Z. Phys. A 352 (1995) 353.

[7] F. C. Barker, Aust. J. Phys. 48 (1995) 813.

[8] M. A. Godwin, R. M. Chasteler, C. M. Laymon, R. M. Prior, D. R. Tilley, and H. R. Weller, Phys. Rev. C 53 (1996) R1.

[9] P. Descouvemont and D. Baye, Nucl. Phys. A 407 (1983) 77; *ibid.* 487 (1988) 420; *ibid.* 573 (1994) 28; T. Mertelmeier and H. M. Hofmann, Nucl Phys. A 459 (1986) 387.

[10] A. R. Edmonds, *Angular momentum in quantum mechanics* (Princeton University Press, 1968).

[11] M. Kamimura, Prog. Theor. Phys. Suppl. 68 (1980) 236.

[12] A. Csótó, Phys. Lett. B 315 (1993) 24.

[13] A. Csótó, K. Langanke, S. E. Koonin, and T. D. Shoppa, Phys. Rev. C 52 (1995) 1130.

[14] A. Csótó, R. G. Lovas, and A. T. Kruppa, Phys. Rev. Lett. 70 (1993) 1389.

[15] K. Wildermuth and Y. C. Tang, *A Unified Theory of the Nucleus* (Vieweg, Braunschweig, 1977).

[16] B. Mainsbridge, Nucl. Phys. 21 (1960) 1.

[17] N. B. Shul'gina, B. V. Danilin, V. D. Efros, J. M. Bang, J. S. Vaagen, and M. V. Zhukov, Nucl. Phys. A 597 (1996) 197.

[18] D. C. Zheng, B. R. Barrett, J. P. Vary, W. C. Haxton, and C.-L. Song, Phys. Rev. C 52 (1995) 2488.

[19] OXBASH-MSU (the Oxford-Buenos-Aries-Michigan State University shell model code). A. Etchegoyen, W. D. M. Rae, and N. S. Godwin (MSU version by B. A. Brown, 1986); B. A. Brown, A. Etchegoyen, and W. D. M. Rae, MSUCL Report Number 524 (1986) (unpublished).

[20] S. Cohen and D. Kurath, Nucl. Phys. 73 (1965) 1.

[21] B. A. Brown, A. Csótó, and R. Sherr, Nucl. Phys. A 597 (1996) 66.

FIGURES

FIG. 1. ^{7}Li$(p,\gamma_0)^8$Be astrophysical S factor as a function of the ^{7}Li+p center-of-mass energy. The result of the present calculation is given by the solid line, while the $E1$ and $M1$ contributions are given by the dashed and dot-dashed lines, respectively. The data are those of Zahnow *et al.* [5].

FIG. 2. As for Fig. 1, but displayed on a linear scale.

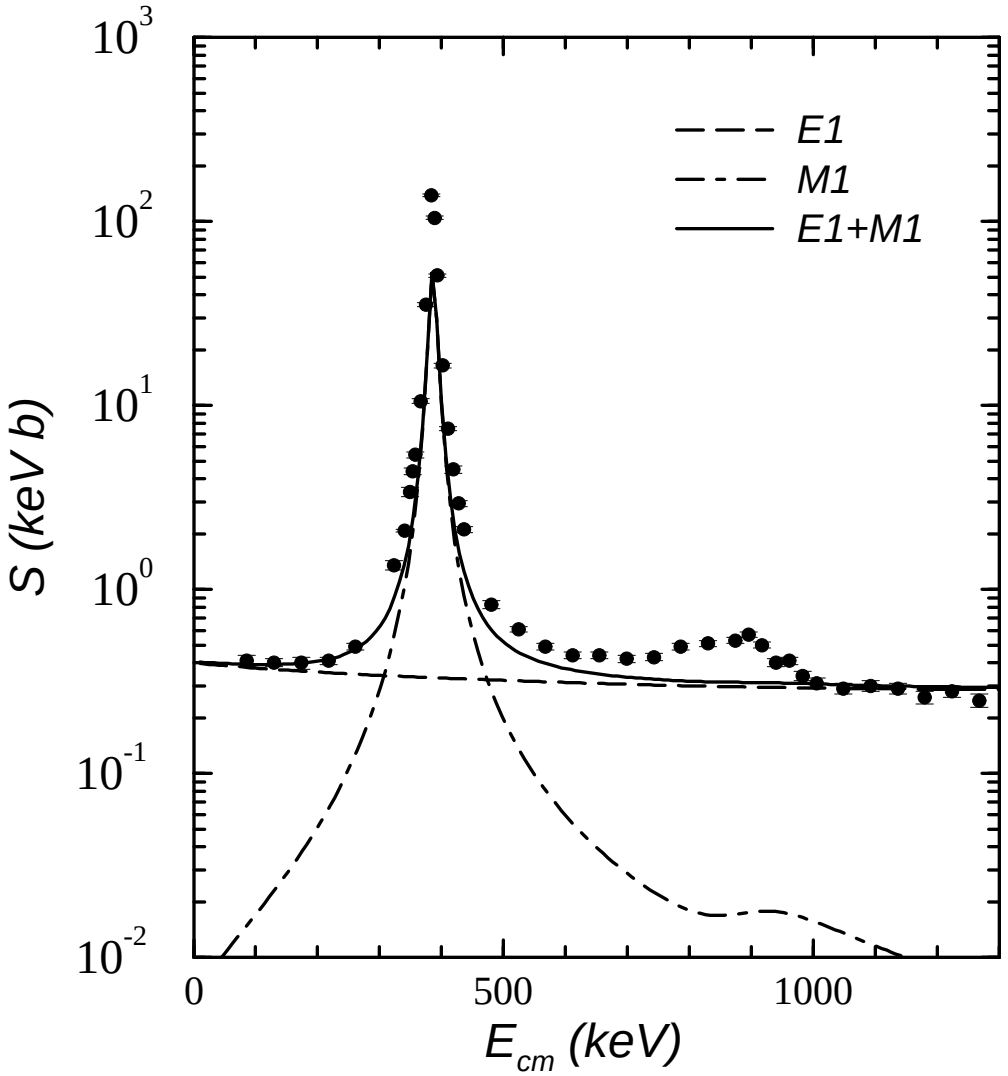
TABLES

TABLE I. Spectroscopic amplitudes, S_I, labeled by the channel spin I for the ^{7}Li$(p,\gamma)^8$Be reaction to the 1^+ states in ^{8}Be, as obtained from the shell model calculations using the interactions of Zheng *et al.* [18] and of Cohen and Kurath [20].

			S_I	
State	$E_{c.m.}$ (keV)	I	Zheng	CK
$1^+;1$	386	1	0.3499	0.2644
		2	0.2774	0.3910
$1^+;0$	897	1	−0.2612	−0.2773
		2	0.5132	0.5623

TABLE II. Spectroscopic amplitudes, θ_j, for the ^{7}Li$(p,\gamma)^8$Be reaction to the 1^+ states in ^{8}Be, as obtained from our shell model calculations.

			θ_j	
State	$E_{c.m.}$ (keV)	j	Zheng	CK
$1^+;1$	386	$0p_{3/2}$	0.4327	0.4009
		$0p_{1/2}$	−0.1104	−0.2490
$1^+;0$	897	$0p_{3/2}$	−0.0290	−0.0334
		$0p_{1/2}$	−0.5752	−0.6266


E1
M1
E1+M1
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E_cm (keV)
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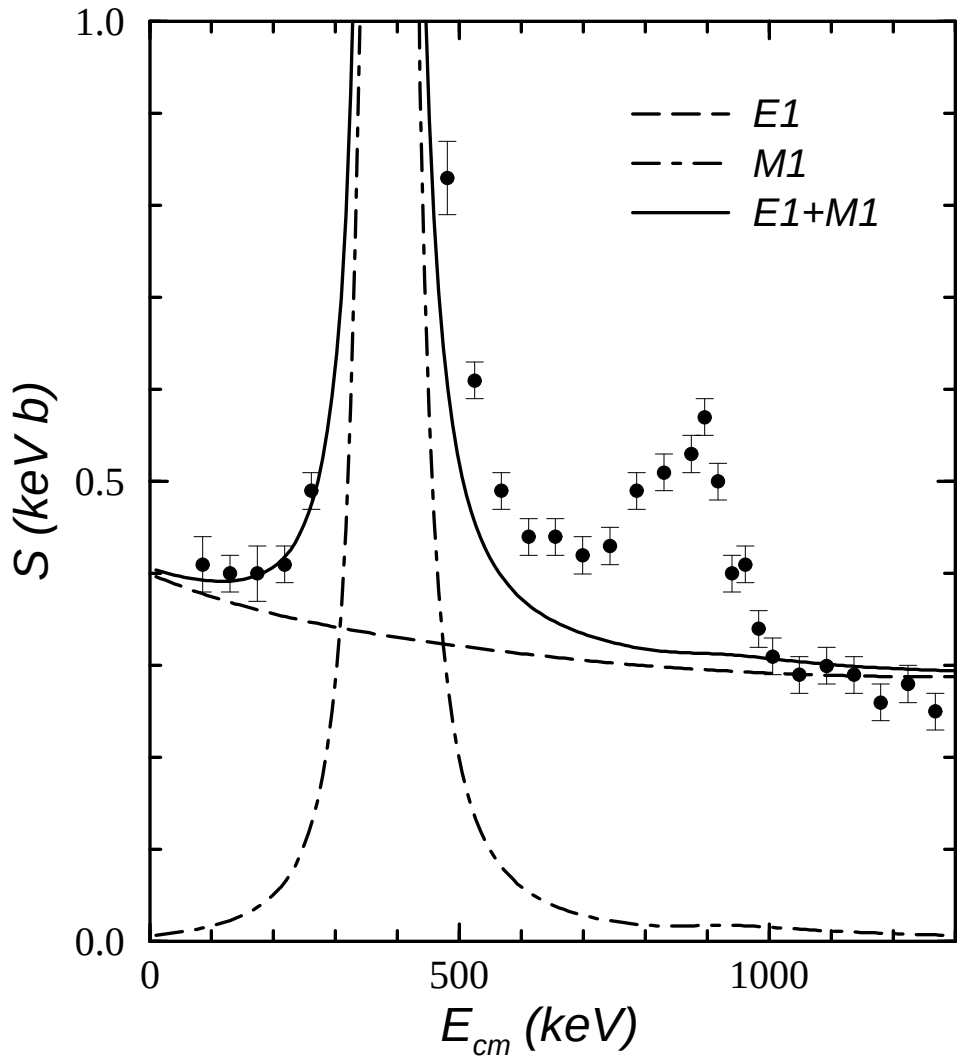
10^2
10^1
10^0
10^-1
10^-2
0
500
1000


1.0
0.5
0.0
0
500
1000
S (keV b)
E_cm (keV)
E1
M1
E1+M1